Phys 131
Fall 2015

Fundamental Mechanics: Class Exam I

9 September 2015

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Instructions

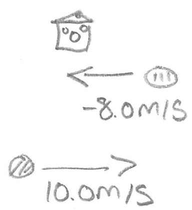
- There are 8 questions on 5 pages.
- Show your reasoning and calculations and always justify your answers.

Physical constants and useful formulae

$$g = 9.80\,\mathrm{m/s^2}$$

Question 1

At *one instant* a mouse passes a piece of cheese while running left with speed 8.0 m/s. After moving left for a while, the mouse turns around and runs right. At a *later instant* it passes the same piece of cheese while running right with speed 10.0 m/s. The time taken between these instants is 3.0 s. Determine the average acceleration of the mouse between these instants.



$\mathrm{Avg}\,A = \frac{\Delta V}{\Delta t}\ \frac{10+8}{3-0} = \frac{18}{3} = 6\,\mathrm{m/s^2}$

$\boxed{\mathrm{Avg}\,A = 6\,\mathrm{m/s^2}}$

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Question 2

A ball, attached to a stretchy string, falls down, stretching the string. The ball eventually reverses direction and moves up. Which of the following (choose one) is true of the ball's acceleration *at its lowest point*? Use coordinates where upward is positive.

i) $a = 0\,\mathrm{m/s^2}$
ii) $a > 0\,\mathrm{m/s^2}$
iii) $a < 0\,\mathrm{m/s^2}$
iv) $a = -9.80\,\mathrm{m/s^2}$

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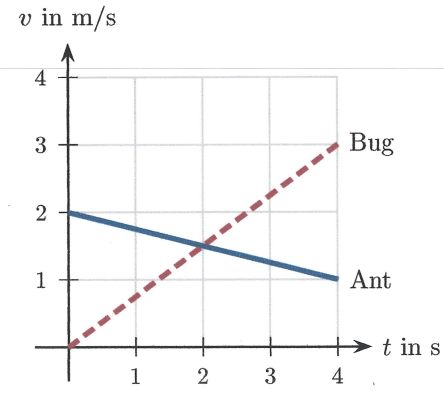
The acceleration is positive because it is changing from negative to positive

$\Delta x =$ area under curve

Question 3

An ant and a bug walk along straight sticks. The solid graph illustrates the ant's velocity vs. time. The dashed graph indicates the bug's velocity vs. time. Which of the following (choose one) is true regarding the displacement (change in position) of the bug, Δx_{bug}, compared to that of the ant, Δx_{ant}, from 0 s to 4 s?



i) $\Delta x_{\text{bug}} = \Delta x_{\text{ant}}$.

ii) $\Delta x_{\text{bug}} > 0$ and $\Delta x_{\text{ant}} < 0$, so $\Delta x_{\text{bug}} > \Delta x_{\text{ant}}$.

iii) $\Delta x_{\text{bug}} > 0$ and $\Delta x_{\text{ant}} > 0$, but $\Delta x_{\text{bug}} > \Delta x_{\text{ant}}$.

iv) $\Delta x_{\text{bug}} > 0$ and $\Delta x_{\text{ant}} > 0$, but $\Delta x_{\text{bug}} < \Delta x_{\text{ant}}$.

$6 = 4+2 \quad 6=6$ ✓

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Question 4

Consider the vectors

$$\vec{A} = 6\hat{\mathbf{i}} + 2\hat{\mathbf{j}} \text{ and}$$
$$\vec{B} = 7\hat{\mathbf{i}} - 4\hat{\mathbf{j}}.$$

Let $\vec{C} = \vec{A} - 2\vec{B}$. Express $\vec{C}$ in component form and determine the magnitude of $\vec{C}$.

$\vec{A} = 6\hat{i} + 2\hat{j}$

$\vec{B} = 7\hat{i} - 4\hat{j}$

$-\vec{B} = -7\hat{i} + 4j$

$-2\vec{B} = -14\hat{i} - 8\hat{j}$

$2\vec{B} = 14\hat{i} - 8\hat{j}$

$\vec{C} = (6\hat{i} + 2\hat{j}) - (14\hat{i} - 8\hat{j})$

$\boxed{\vec{C} = -8\hat{i} + 10\hat{j}}$

$C = \sqrt{-8^2 + 10^2}$

$C = \sqrt{64 + 100}$

$\boxed{C = \sqrt{164}}$

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$V_1x = V_0x + ax\Delta t$

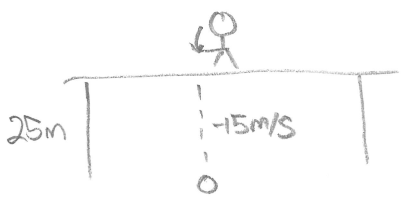
$X_1 = X_0 + V_0x\Delta t + \frac{1}{2}ax(\Delta t)^2$

$V_1x^2 = V_0x^2 + 2ax\Delta X$

Question 5

A person stands on a bridge and throws a ball vertically down to a river below. The ball leaves the hand with speed 15 m/s at a height of 25 m above the water. Ignore air resistance in the following.

a) Determine the speed of the ball at the moment just before it hits the water.



$V_1y^2 = -15(m/s)^2 - 19.6\, m/s^2(-25m)$

$V_1y^2 = 225(\frac{m}{s})^2 + 490(\frac{m}{s})^2$

$-V_1y^2 = -715\, m^2/s^2$

$V_1y = -26.7\, m/s$

$\boxed{26.7\, m/s}$

$t_0 = 0s$, $x_0 = 0m$, $y_0 = 25m$, $V_{0x} = 0\, m/s$, $V_{0y} = -15\, m/s$, $a_{0y} = -9.8\, m/s^2$

$t_1 = 1.2s$, $X_1 = 0m$, $Y_1 = 0m$, $V_1x = 0\, m/s$, $V_1y = \cancel{26.7\, m/s}$, $a_1y = -9.8\, m/s^2$

$\Delta y = (0m - 25m)$

$\Delta y = (-25m)$

b) Determine the time taken to reach the water.

$Y_1 = y_0 + v_{0y}\Delta t + \frac{1}{2}a_y(\Delta t)^2$

$0m = 25m - 15m/s\,\Delta t - 4.9(\Delta t)^2$

$0 = -4.9(\Delta t)^2 - 15\Delta t + 25$

$\boxed{\Delta t = 1.2s}$

$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

c) Will the speed of the ball when it hits the water be different (to that of the case in part a) if it were thrown directly up at 15 m/s? Briefly explain your answer.

~~Yes because the ball will have to travel a farther distance downward once it reaches its max height of being thrown upword. Since g is (-9.8 m/s²), that will be acting on the downward velocity until it hits the water.~~

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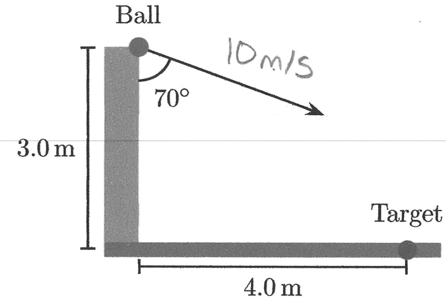
NO

Question 6

A person stands on a wall and attempts to throw a ball at a target on the ground below. The ball leaves the person's hand at a height of 3.0 m from the ground. The target is 4.0 m from the base of the wall. The ball is aimed so that it leaves the wall initially traveling with speed, 10 m/s at an angle of 70° from the wall. Determine whether the ball passes above the target and, if so, how high it is when it is directly above the target.



$t_0 = 0s$
$x_0 = 0m$
$y_0 = 3.0m$
$V_{0x} = 9.4 m/s$
$V_{0y} = 3.4 m/s$
$a_y = -9.8 m/s^2$

$t_1 = 0.43$
$x_1 = 4.0 m$
$y_1 = 0.63 m$
$V_{1x} = 9.4 m/s$
$V_{1y} =$
$a_y = -9.8 m/s^2$

$V_{1x} = V_{0x} + a_x \Delta t$
$x_1 = x_0 + V_{0x}\Delta t + \frac{1}{2} a_x (\Delta t)^2$
$V_{1x}^2 = V_{0x}^2 + 2a_x(\Delta x)$

$X = 10 \cos 20$
$Y = 10 \sin 20$

$x_1 = x_0 + V_{0x}\Delta t + \frac{1}{2} a_x (\Delta t)^2$
$4m = 0m + 9.4(m/s)\Delta t$
$\frac{4}{9.4} = \Delta t$

$y_1 = y_0 + V_{0y}\Delta t + \frac{1}{2} a_y (\Delta t)^2$
$y_1 = 3m + 3.4\Delta t - 4.9(\Delta t)^2$
$y_1 = 3m - 3.4(0.43) - 4.9(0.43)^2$
$y_1 = 0.63$

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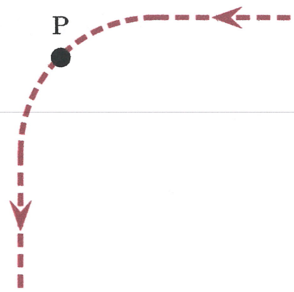
$\boxed{0.63 \text{ m above target}}$

Question 7

An asteroid moves with constant speed, curving along along the illustrated trajectory. Which of the following is true regarding the asteroid's acceleration at the point labeled P?



i) $\vec{\mathbf{a}} = 0$

ii) $\vec{\mathbf{a}} \neq 0$, pointing $\downarrow$

iii) $\vec{\mathbf{a}} \neq 0$, pointing $\searrow$

iv) $\vec{\mathbf{a}} \neq 0$, pointing $\swarrow$

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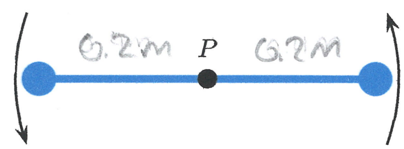
Question 8

A barbell consists two masses at the end of a rod. The distance between the masses is 0.40 m. The barbell rotates at a constant rotates about its midpoint, labeled P, with the ends moving as illustrated. It completes a 15 full rotations every minute. Determine the acceleration of one of the ends of the barbell.



$r = 0.2m$

$a = \frac{v^2}{r}$ $V = \omega r$ $\frac{15 \times 2\pi}{60s} = \omega$ $\omega = \frac{\Delta\theta}{\Delta t}$

$a = \omega^2 r$

$\omega = \frac{\pi}{2}$ radians

$a = \omega^2 r$

$a = \left(\frac{\pi}{2}\right)^2 (0.2m)$

$\boxed{a = 0.49\ m/s^2}$

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